

Special Report

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AMERICA'S SCIENCE TEST

The Tough Road to Better Science Teaching

Proponents of new methods encounter resistance, especially at research universities

By JEFFREY BRAINARD

One might expect California State University at Fullerton, with a history of preparing elementary- and secondary-school teachers, to embrace new but proven methods of instruction. Still, when its biology department began a project a decade ago to overhaul the undergraduate curriculum, the effort bogged down quickly.

Most of the professors wanted to consolidate the department's eight required courses, which they felt covered too much content in too little depth. But they argued endlessly about how that should be done. After two fruitless years of faculty meetings, the department called in a professional facilitator, who helped the participants reach agreement on where to trim and how to incorporate teaching methods proven to develop students' critical-thinking skills and performance.

In all, it took seven years for the changes to be put in place.

"People said, If it ain't broke, why fix it?" recalls Joyce K. Ono, a professor emerita of biology, who helped lead the reform effort.

For decades introductory science courses have relied largely on lectures and tests that reward memorization of facts and formulas, an approach that has driven away many talented students. While new teaching models have shown success in engaging and retaining undergraduates, they have yet to be widely adopted in academe. For one thing, the tenure system rewards good research above good teaching. For another, faculty members have final say over their own courses, and some are resistant to change. Other professors are unaware of the new methods, in part because the federal government has provided only limited financial support for getting the word out.

Proponents of the new models have come up against particularly strong resistance at the nation's research universities, which award most of the undergraduate degrees in science and engineering.

"In almost every discipline, I could point to a variety of really effective, wonderful sets of instructional materials and instructional practices, and say that if we could magically click our fingers and get everybody using them, there would be a huge improvement in undergraduate education that would happen instantaneously," says Myles G. Boylan, who directs a program on undergraduate education at the National Science Foundation that has provided much of the money to develop the teaching models. "But we're nowhere near that."

The Leaky Pipeline

Experts and blue-ribbon reports have for years called for improving college teaching in all disciplines. But science and engineering are getting special attention from Congress and the Bush administration now because of their central role in economic growth.

In the educational pathway from elementary school to graduate study in the sciences, introductory college courses have been identified as a stubborn obstruction. About 30 percent of entering freshmen plan to earn bachelor's degrees in science, mathematics, or engineering, but only about 15 percent of all baccalaureate degrees are awarded in those fields. The percentages are even lower among black and Hispanic students, who make up a growing share of the undergraduate population.

While many science instructors have prided themselves on using introductory courses to "wash out" students who are lazy or lack aptitude, in reality many students who drop their science majors are academically well prepared and motivated, says Elaine Seymour, a sociologist at the University of Colorado at Boulder, who is an author of *Talking About Leaving: Why Undergraduates Leave the Sciences* (Westview Press, 1997). Other students stick it out despite bad teaching. Ms. Seymour believes that academe has made little progress in the decade since she wrote her book.

The improved teaching methods that she and others say have made a difference are often called "student centered" or "inquiry based" learning. They share no common blueprint but do possess some similarities. Instead of one-way lectures, the methods emphasize continual interaction between professors and students, aided by technology, to ensure that the students grasp the material. The curricula emphasize teams of students working together and encourage them to apply scientific principles and reasoning to real-world problems — for example, how the hole in the ozone layer has formed.

A body of evidence, although not complete, suggests that those methods tend to help students retain the material better and perform on standardized tests at least as well as, and in some cases better than, those who were educated in more-traditional ways. In addition, research shows that the new teaching methods help students emerge with a better grasp of the scientific process and the fundamental concepts of physics, chemistry, and other disciplines.

No one can say with much precision how many faculty members are using the new methods and at which institutions. The techniques appear to have made the most inroads at liberal-arts colleges. Those institutions, however, award only 10 percent of baccalaureate degrees in the sciences and engineering. Progress has been slower at research universities, which grant 57 percent of such degrees.

In a survey conducted this spring by the Reinvention Center, a project based at the University of Miami to improve undergraduate teaching at research universities in all disciplines, only about 20 percent of institutions reported offering as many as 50 to 75 introductory courses using the new methods. Forty-five percent said they offered 25 to 50. The percentages are almost identical to those from a similar survey the project conducted in 2001.

Stick to Your Research

While college leaders talk about the importance of better teaching at their institutions, the academic departments controlling tenure decisions fear that an emphasis on teaching will lead them to fall behind peers at other institutions in the race for prestige, in which the winners are determined by their research productivity.

When the new methods have been embraced, it has usually been by individual faculty members fed up with the results of traditional teaching. These academics include prominent physicists like Harvard University's Eric Mazur and the University of British Columbia's Carl E. Wieman. But only a few research institutions have adopted the new approaches extensively.

One is the University of Rochester, which adopted "peer-led team learning" in 1995. It emphasizes small groups of students working together to solve problems. Some undergraduates receive special training, concurrent with the course, to help lead the groups.

The approach is now used in most of Rochester's introductory courses in science, enrolling 2,500 students annually across eight departments, says Jack Kampmeier, a professor emeritus of chemistry, who helped lead the effort. "A major force in propagating the model were the students themselves," he says. "The peer leaders became absolutely invested in the model and became enthusiastic spokespeople for it."

Faculty members who have pressed colleagues to try out the new teaching methods say many express interest. But hostile reactions are plentiful, too.

Robert J. Beichner, a physics professor at North Carolina State University, has heard the skeptics at institutions that have invited him to describe Scale-Up, a teaching method he developed. He tells his audiences about findings from educational psychology and cognitive science that influenced the approach, in which teams of students seated at round tables, supplied with laptop computers, brainstorm solutions to physics problems.

After one recent presentation, a faculty member asked him, "When you get done playing all these games, when do you actually teach physics?"

Mr. Beichner responded with data, hoping to appeal to his critic's respect for hard evidence: Students in the Scale-Up classes at North Carolina State had a failure rate one-third that of students in traditional classes.

But, he and other reformers say, appealing to reason goes only so far. Fear has its place, too.

"If all that a university can do is offer a large lecture hall with somebody talking at students," he tells colleagues, "you can easily do better than that with the University of Phoenix or Western Governors University." Students can replay those institutions' online lectures if they miss a point. Professors should give students "some reason to go to a brick-and-mortar university." Otherwise, he warns, faculty members will be out of work.

Innovators like Mr. Beichner are limited in what they can achieve, says Susan B. Millar, a senior scientist in the School of Education at the University of Wisconsin at Madison who studies teaching in science and engineering. "I don't know that you can take these kinds of programs to scale when the unit of change is the individual," she says. "You can only do that for so long, until you get tired or retire. And then it doesn't spread."

Top administrators are loath to force change on departments. "I'm very reluctant to define successful and unsuccessful ways in which this can be done," says Patrick V. Farrell, provost and vice chancellor for academic affairs at Madison, where some of the new teaching methods were developed. "I don't want to say, 'Lectures don't work, but group learning does.' In some contexts that's true; in other contexts, it's not. I'm looking for effectiveness in helping students learn."

For Want of Funds

Another barrier to the new teaching methods is that the federal government has spent little to spread the word among faculty members.

For two decades, the National Science Foundation has been the leading sponsor of research into the teaching of science and engineering and how students learn in those disciplines. The agency finances projects to spread the new teaching methods through a program in its education directorate called Course, Curriculum, and Laboratory Improvement. The program's budget of \$34-million this year is down from a high of \$56.4-million in 2002, a consequence of a declining budget for the NSF's education division over all. The new Democratic leadership in Congress, however, has promised a large increase for the division in 2008.

The program spends about half its budget to develop new instructional materials and methods. The remaining money goes to encourage the wider use of existing ones. Some grants pay for faculty members in science to adapt the new methods to their own courses.

The NSF also supports regional workshops, lasting up to two weeks, to introduce professors to the techniques. As recently as 1999, the foundation awarded eight grants to support such workshops, but this year it awarded only four. The sessions apparently helped to get faculty members' attention: 76 percent of survey respondents who attended one set of workshops, on new methods for teaching chemistry, said they had started at least one project described in the sessions after returning to their home campuses. In all,

that set of workshops drew 900 attendees in 27 states.

Some educators argue that the NSF and its course-improvement program should devote more attention and money to workshops and other efforts to spread the proven teaching methods. This year the program expects to award some 90 grants, of up to \$200,000 each, for projects to develop new teaching methods. Those projects tend to revisit well-trod topics in marginally new ways, says Ms. Seymour, the Colorado sociologist.

"We don't need any more new ideas" about teaching science, she says. "We need consolidation of what works. But the NSF is not set up to do that."

Consolidation largely runs against the agency's own culture and mission, which are focused on discoveries, says the NSF's Mr. Boylan, who directs the improvement program.

His agency's stance reflects a similar bias among college professors, says Norman L. Fortenberry, director of the Center for the Advancement of Scholarship on Engineering Education at the National Academy of Engineering.

"For most faculty, there are relatively few incentives for picking up somebody else's work and using it," he says. Candidates for tenure who work on dissemination projects face what he calls the "not-invented-here syndrome": Reviewers ask them, "This wasn't produced by you, so why should I give you credit for it?"

Accreditors Weigh In

Advocates of change have been working on several tools to help overcome that bias.

One is accreditation. Engineering colleges appear to be further along than their colleagues in science departments, in part because their accreditor, ABET Inc., specifically required student-centered teaching in the standards it released in 1996. A study by Pennsylvania State University in 2005 found that engineering students taught this way improved their scores in math and science as well as on tests of skills like written communication.

Mr. Fortenberry calls that outcome "a great start" but adds that disincentives remain for faculty members to focus on teaching. And most scientific disciplines lack specific accreditors.

Some academics believe that the key will be to train the next generation of faculty members to use the new teaching methods, in the hope that they will cajole and inspire their colleagues. Some projects toward that end are more intensive than the National Science Foundation's short workshops.

The principal effort is led by the University of Wisconsin at Madison. In 2003 the NSF gave the university a five-year, \$10-million grant to establish the Center for the Integration of Research, Teaching, and Learning. The center has worked with more than 1,000 new faculty members and graduate students at Madison and other universities to try the new teaching methods and conduct research on the process of putting them into practice.

The project also works on ways to attract science professors to join in the innovation. Trying the new teaching methods, the center's leaders say, should be viewed as conducting an experiment with measurable results — an approach that appeals to the instincts of researchers. Organizers also argue that the new methods are more professionally satisfying than delivering conventional lectures.

Observers hope that the Wisconsin project will show results different from those of a similar NSF-financed effort that ran from 1993 to 2002. An evaluation of that program found that participants, who were graduate students, rated it highly but felt pressure to "conceal" the work from their professors, who viewed it as distracting them from research. What's more, the new teaching methods often did not take root in the students' departments, which was a goal of the project.

If young researchers delay trying the new teaching methods until their careers are established, though, they may put the attempt off for good, advocates say. And if American science is to stay competitive, that is

a problem. "We don't really have the time to wait around for another 20 years," says Madison's Ms. Millar, "for this kind of sea change to occur."

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